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Logging Damage

January 9, 1939

DAMAGE TO RESERVE STAND AND REPRODUCTION BY LOGGING AND SLASH DISPOSAL IN PONDEROSA PINE IN CENTRAL IDAHO

By

Edwin L. Mowat, Assistant Silviculturist,
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Ogden, Utah.

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INTRODUCTION

Methods of logging and of slash disposal in partial cuttings are rarely determined entirely by the amount of damage to the reserve stand and reproduction. Yet it is possible to hold such damage to a minimum by the enforcement of reasonable rules and slight modifications in practice, and this should be done wherever continued forest production is the aim of management. This is particularly important in the ponderosa pine forests of the West because of the large dependence upon advance reproduction for adequate stocking after cutting.

A body of specific information upon the losses incident to the various stages of a cutting operation, as related to different methods of logging and slash disposal and to minor modifications in these methods, should be available to the forester or timber operator if he is to properly weigh this factor in planning his cutting procedure and regulations. Specific data of this nature are relatively scarce and incomplete, at least in published form. Logging damage is to a considerable degree a local problem because of the wide variation in topography, soil, ground cover, and character and quantity of advance growth from one region to another or even from spot to spot within a given tract. But there are some elements

in common which make the knowledge of local results of some general value. It is thus hoped that the present report, although dealing with only one ponderosa pine operation in central Idaho, will add a little to the inadequate body of facts on this subject and perhaps serve as a standard for comparison of other methods and conditions.

PREVIOUS STUDIES

The few published results of previous studies of logging damage in ponderosa pine include Brown's (1) comparison of damage by various logging methods in the California pine region and in the Southwest, Wales' (7) discussion of damage by tractor skidding in Arizona, Perry's (5) comparison of losses on a central Oregon operation by four methods of skidding, and brief but informative paragraphs on damage by various logging methods in the bulletins on timber growing and logging practice (3, 6, 8). The other losses and injuries incident to selective cuttings, including those from different methods of slash disposal, are also mentioned in the latter publications. Munger and Westveld (2) give some of the most complete and specific data available on destruction and injury of reproduction and reserve trees by various methods of slash disposal. Destruction of advance growth by slash burning is so extremely variable, not only with locality but also with weather conditions and human factors that specific local figures on this loss have often been considered of little general value. The recent bulletin on slash disposal in the Southwest (4) dismisses the subject on this basis. The probability of some damage from this source should not be neglected, however, and data on its magnitude and variations are included in the present report to make the record of changes complete.

8 room cut actually
but 15 room cut

DESCRIPTION OF AREA AND OPERATION

The data presented here are based on the records of seven 10-acre sample plots scattered irregularly through a national forest timber sale area of 1,900 acres, now forming part of the Boise Basin Experimental — ? Forest in Idaho. The topography is moderately rough, with slopes commonly of 20 to 50 percent and in places up to 80 percent. The stand was uneven-aged ponderosa pine with mature and overmature classes predominating and an average mixture of about 15 percent Douglas fir by volume. The average stand on the plot area before cutting contained 2,692 seedlings and saplings, 66 poles, and 31 sawlog or timber trees per acre.

On the general sale area, trees were marked by the "economic selection" method, removing on the average about 50 percent of the original sawlog volume of 12,160 board feet per acre. Five of the sample plots were cut by special methods, as listed in Table 1, but all would class as selective cuttings.

Logs were cut in long lengths (32 to 40 feet), bunched by caterpillar tractors, and skidded to the railroad by tractors with fairlead arches, or in a few cases with pans. The study plots included a fair proportion of main "arch roads," but no railroads or railroad landings. Slash was piled and burned on about one-half the area of each plot and left untreated on the other half. It was piled during the summer and burned following moderate rains in early November, 1933.

Table 1.- Volume[1/] and method of cutting on sample plots

Plot No.	Original Stand	Cut	Per Acre Reserve Stand	Percentage cut	Type of cutting
	Bd. Ft.	Bd. Ft.	Bd. Ft.	%	
3	24,688	20,110	4,578	82	24" Flexible Dia. Limit
6	21,713	17,275	4,438	80	Tree class selection
1	14,463	13,809	654	96	15" Rigid Dia. Limit
2	21,172	13,587	7,585	64	Economic selection
4	14,334	12,817	1,517	89	Scattered seed tree
5	21,740	11,222	10,518	52	Economic selection
7	17,642	9,176	8,466	52	Tree class selection
Av.	19,253	13,967	5,286	72	

1/ Volume in board feet as given in this and subsequent tables is that in trees larger than 9.5 inches d.b.h., as determined from volume table, giving merchantable volume (Scribner Dec. C) to an 8-inch top.

CLASSIFICATION OF DAMAGE

Logging damage consisted of: (1) trees and reproduction immediately destroyed by felling and skidding, with which may be included those dying from the same causes within a year; (2) severely injured trees dying within a year from barkbeetle attack or windthrow; and (3) injuries to living reserve trees. The only form of destruction by slash disposal discussed here is killing by slash fires. Other losses which may be ascribed largely to logging influence are uninjured trees windthrown or killed by barkbeetles within one year.

Three size classes of trees were distinguished: (1) reproduction - seedlings and saplings up to 3.5 inches d.b.h.; (2) poles - 3.6 inches to 9.5 inches d.b.h.; and (3) timber trees - larger than 9.5 inches d.b.h. The record of damage to poles and timber trees is based upon the entire plot area, 72 acres; damage to reproduction, upon 12 transects subdivided into 600 2-milacre quadrats. The reproduction record did not distinguish felling from skidding losses nor did it segregate initial from subsequent losses. In addition to the tabulations by numbers of trees and volume, gross logging and slash-burning losses are expressed in terms of decrease in percentage of area stocked. Some of the data are listed by individual plots to indicate variation that may be expected and to show relations to volume cut and to reserve stand.

LOGGING DAMAGE

Direct Losses Caused by Felling and Skidding

The destruction of reserve trees by logging damage alone amounted to 1,070 seedlings and saplings, 7.5 poles, and 0.7 timber trees per acre for all plots (Table 2). The proportions of original numbers of trees destroyed

were 40, 11, and 4 percent for the 3 size classes. Skidding destroyed a few more poles than felling, while the latter was responsible for nearly all of the damage to timber trees. By far the greater part of the loss of reproduction was caused by skidding.

Table 2.- Trees destroyed by logging

Plot No.	No. Killed per Acre: Reproduction	Poles	Timber Trees	Volume Loss Per Acre: Cu. Ft. 1/	Bd. Ft.	Percentage of No. Unmarked Trees: Reproduction	Poles	Timber Trees	Poles and Timber
						%	%	%	%
				Felling Damage					
3		7.7	1.1	83.1	354		6.1	6.7	6.2
6		4.8	0.6	41.8	165		6.8	4.3	6.4
1		3.3	0.4	14.7	30		5.3	4.1	5.1
2		2.7	1.0	49.5	238		7.0	3.3	5.4
4		1.9	0.0	2.3	0		2.9	0	2.7
5		3.1	1.1	56.6	236		5.6	3.0	4.6
7		1.2	0.4	19.9	78		2.8	3.1	2.9
Av.		3.5	0.6	37.3	156		5.3	3.6	4.9
				Skidding Damage					
3		8.9	0	9.0	0		7.1	0	6.3
6		5.9	0	5.6	0		8.4	0	7.0
1		3.4	0.4	12.4	13		5.4	4.1	5.2
2		3.6	0	6.6	0		9.4	0	5.3
4		2.2	0	2.1	0		3.3	0	3.0
5		3.4	0	3.6	0		6.2	0	3.7
7		1.2	0	1.3	0		2.8	0	2.1
Av.		4.0	0.1	5.8	2		6.1	0.3	4.9
				Felling and Skidding Damage					
3	808	16.6	1.1	92.1	354	42.6	13.2	6.7	12.5
6	1,058	10.7	0.6	47.4	165	35.0	15.2	4.3	13.4
1	1,600	6.7	0.8	27.1	43	39.6	10.7	8.2	10.3
2	750	6.3	1.0	56.1	238	47.6	16.4	3.3	10.7
4	1,775	4.1	0.0	4.4	0	44.8	6.2	0	5.7
5	138	6.5	1.1	60.2	236	37.9	11.8	3.0	8.3
7	°	2.4	0.4	21.2	78	°	5.6	3.1	5.0
Av.	1,070	7.5	0.7	43.1	158	40.3	11.4	3.9	9.8

° No data

1/ Volume in cubic feet, as given in this and subsequent tables and text, is total volume inside bark of trees larger than 3.5 inches d.b.h., as read from volume table.

Destruction of poles and sawlog trees was greatest on the plot with the heaviest volume cut and least on the plot with the lightest cut. Within these extremes, however, there was no consistent ratio of loss to cut, as other factors such as topography, spacing of trees on the ground, size and character of reserve stand, and method of marking materially affect damage. The average loss was equivalent to about 1 tree by felling and 1 tree by skidding per 3,400 board feet cut per acre, with a range of from one-half to twice this amount. Damage to reproduction showed practically no relation to volume cut (within the limited range of cut on these plots, 9 M to 20 M per acre), but varied directly and fairly consistently with number of seedlings originally present. Although the numbers of seedlings destroyed varied widely, the percentage loss was relatively constant.1/ 2/

Method of cutting was related to logging damage largely insofar as it determined volume cut, but additional influences are evident in the case of certain plots. Thus on plots 1, 4, and 6, representing a 15-inch-diameter-limit cutting, a modified seed tree cutting, and a tree class selection respectively, many trees of intermediate size (10-18-inch d.b.h.) were marked to cut and hence even if smashed were not charged to logging damage. As a result, the number of timber trees destroyed (table 2) is

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1/ ~~The higher rate of loss (64 percent) on Plot 5 was due to the much smaller number of seedlings present and to the steep topography and the character of the stand, which permitted free skidding on all parts of the plot.~~

2/ This paragraph should be adequate for most purposes, but further discussion of relationships, or lack of them, in the following four paragraphs is included in this base report for the benefit of those curious about the effects of "other factors" mentioned above.

relatively small, although, because of lighter reserve, the percentage loss is not necessarily low. Plot 7, although cut according to the same principles as plot 6, showed a smaller loss than the latter in all classes of material because of a lighter cut and also fewer understory trees in the original stand.

The other "statistics" of the cutting, such as original stand and volume, number of trees and percentage cut, and number and volume in reserve stand, are mostly correlated with volume cut (other things being equal), so that the latter is the best single index of damage, even though its relationship to loss is not precise. Number of trees cut per acre might show a satisfactory direct relation to damage where a single method of cutting is used, but it did not in this study. Destruction of reproduction seemed to show more relation to original quantity present than to other factors - apparently the beneficial effect of a lighter volume cut is offset by the fact that light cut often means a light merchantable stand with which is associated a heavy stand of reproduction, so that many seedlings are destroyed by skidding even for the few trees cut. There was a rough relationship of reproduction losses to percentage cut. It is only reasonable to assume that with two stands of similar character in all respects, the reproduction losses, like damage to larger trees, would be greater in the one with heaviest volume cut.

Stand distribution, either of original or of cut trees or of reserve trees and reproduction, causes large variations in damage, but it is not readily subject to numerical expression and can be given only a general average weighting by raising or lowering the estimate of probable losses on a given tract where unusual conditions prevail. In general, a groupwise arrangement of age classes is most favorable from the standpoint of logging damage.

Topography is another factor that sometimes materially influences logging damage but that must be rated by personal judgment. Smooth topography should mean less destruction, as felling is better controlled, there is more choice of skidding routes, and the surface is less disturbed. However, steep slopes and broken topography, although conducive to greater losses in skid trails because of the grinding of tractor treads, may have the effect of confining main skid trail travel to fewer routes so that the total damage would be no greater than on smoother ground. Dense undergrowth of saplings, poles, or brush may have similar opposing effects.

The loss of poles and timber trees, either in numbers or in volume, does not appear particularly serious in stands with as large a reserve as indicated here. The volume loss in cubic feet, however, does represent about 4 years' net growth of such stands, and much of it was in choice trees that would have produced wood at a maximum rate. Thus it is not to be ignored. The destruction of more than 40 percent of the reproduction is a relatively serious loss. Although there remains an average of 1,580 seedlings per acre (where slash was not burned), their distribution is very patchy and many portions of the area are without trees of any size. Subsequent seeding-in may eventually restock these blanks, but in the five years since logging the establishment of new seedlings has been negligible in spite of two good seed crops in this period.

Indirect Losses from Logging

Trees that are scarred, bent, or broken by logging are particularly subject to attack by barkbeetles and to windthrow and occasionally to crushing by snow. Such losses occurring within one year following cutting may reasonably be ascribed primarily to logging injury. This loss amounted to

33 poles and 12 timber trees on the total area or 0.5 poles and 0.2 timber trees per acre (table 3). All of this loss was caused by barkbeetles except two timber trees that were windthrown. The loss in volume was 7.8 cubic feet or 35 board feet per acre. Losses show no definite relationship to volume cut nor to other factors, probably because of inadequate data and because post-logging kill by barkbeetles is very spotty in character. Injured trees that were subsequently killed by slash burning are included with uninjured trees under the latter heading, as only in rare instances would the presence of injuries make the trees more susceptible to fire killing.

Table 3.- Injured trees killed by barkbeetles and windthrow

Plot No.	No. Killed Per Acre		Volume Loss Per Acre		Percentage of Reserve Stand		
	Poles	Timber Trees	Cu. Ft.	Bd. Ft.	Poles	Timber Trees	Total
					%	%	%
3	1.2	0.4	34.7	179	1.1	2.7	1.3
6	0	0.1	1.6	5	0	0.7	0.1
1	0.9	0.1	2.2	2	1.6	1.1	1.5
2	0	0.3	7.2	30	0	1.0	0.5
4	0.9	0	0.9	0	1.5	0	1.4
5	0.1	0.3	9.2	36	0.2	0.8	0.5
7	0	0	0	0	0	0	0
Av.	0.5	0.2	7.8	35	0.8	1.0	0.8
Barkbeetles Av.	0.5	0.14	6.2	27	0.8	0.8	0.8
Windthrow Av.	0	0.03	1.6	8	0	0.2	0.04

Injury to Living Trees

The third class of logging damage is injury to living reserve trees. The four specific kinds of injury listed in this study and the proportion of total reserve trees injured in each way are as follows: top broken, 2.0 percent; top side-swiped, 3.4 percent; serious lean, 1.0 percent; butt or

bole scarred, 4.3 percent. Total number of trees injured was 450, or 6.2 per acre, comprising 8.4 percent of the stand. Damage was recorded only where it was considered serious enough to materially affect the form, quality, or rate of growth of a tree, so these figures are conservative. Further details as to number and size of trees injured and variation by plots are given in table 4. Injuries may also be roughly classified by cause: felling damage - 58 percent; skidding damage - 42 percent of total trees injured. Although more than twice as many poles were injured as larger trees, the percentage of the latter injured was greater than that of poles. Douglas fir suffered relatively more than ponderosa pine, particularly in the form of side-swiping. The difference in species is due in part to the growth of fir in denser stands where injury is unavoidable, and to some degree to a natural lower resistance of its fine limbs to breakage and of its bole to scarring.

Of the seedlings and saplings left after logging, 197 per acre or 14.4 percent of the total were noted as seriously injured. These are principally direct logging injuries, but no distinction was made in the record as to character or cause of injury, so that a very small proportion may have been caused by slash burning. Percentages injured on individual plots ranged from 9.4 to 18.0 percent.

The importance of this form of damage is difficult to estimate in numerical terms. Although an appreciable number of trees were injured, some of them so severely that they can never develop into valuable sawlog trees, many will recover, with only retarded growth and perhaps a small deduction for defect in final sawlog volume as the net effects. Some trees will die of suppression in the natural development of the

Table 4.- Trees injured in logging

(a) Totals by plots, both species, poles and timber trees, by kind of damage

Plot No.	Kind of Damage: Top Broken	Side-Swiped	Lean	Scar	Total	Top Broken	Side Swiped	Lean	Scar	Total
	No. Trees Injured					Percentage of Total Reserve Trees				
						%	%	%	%	%
3	13	56	15	50	110	1.0	4.5	1.2	4.0	8.8
6	22	22	15	44	78	3.0	3.0	2.0	5.9	10.5
1	28	22	4	30	60	4.3	3.4	0.6	4.6	9.1
2	18	41	5	43	86	2.9	6.7	0.8	7.0	14.0
4	15	25	7	27	56	1.9	3.1	0.9	3.3	6.9
5	9	13	4	26	42	1.2	1.7	0.5	3.3	5.4
7	4	5	2	13	18	0.7	0.9	0.4	2.4	3.4
Total	109	184	52	233	450	2.0	3.4	1.0	4.3	8.4
	(b) Average per acre by species and size									
Ponderosa pine:										
Poles	1.14	1.49	0.62	2.03	3.97	2.13	2.78	1.17	3.79	7.42
Timber	0.29	0.61	0.03	0.89	1.57	2.00	4.17	0.19	6.07	10.05
All	1.43	2.10	0.65	2.92	5.44	2.10	3.08	0.96	4.28	8.00
Douglas fir:										
Poles	0.05	0.15	0.06	0.17	0.38	1.19	3.27	1.19	3.57	8.03
Timber	0.03	0.31	0.01	0.15	0.43	1.36	14.97	0.65	7.48	21.10
All	0.08	0.46	0.07	0.32	0.81	1.24	6.83	1.03	4.76	12.00
Both Species:										
Poles	1.19	1.64	0.68	2.20	4.35	2.05	2.82	1.17	3.77	7.47
Timber	0.32	0.92	0.04	1.04	1.90	1.92	6.32	0.25	6.24	11.40
All	1.51	2.56	0.72	3.24	6.25	2.02	3.42	0.97	4.32	8.35

stand; injury to these is of no consequence. Butt or bole scars on ponderosa pine may result in the formation of mass pitch in the nearby wood, rarely in the entrance of decay. Scars on Douglas fir, however, very frequently open the way for wood-rotting fungi, which may eventually destroy a large portion of the bole. In both species such scars are very likely to develop into serious fire scars if a surface fire should run over the area. The permanent sample plots records will eventually provide information on the final losses resulting from these injuries, but not for several decades.

DAMAGE BY SLASH BURNING

The direct losses from the burning of piled slash are listed in table 5. The data for Plot No. 5 are omitted because an accidental summer fire burned over a portion of the plot and losses caused by that and by later slash burning could not be distinguished. Approximate figures for reproduction kill by burning were derived by subtracting the proportion of losses on the unburned portion of each plot (i.e., logging losses alone) from the total losses on the burned portion.

Table 5.- Trees destroyed by slash burning

Plot No.	Number Killed Per Acre: Reproduction	Poles	Timber: Trees	Volume Loss Per Acre: Cu.Ft.	Bd.Ft.	Percentage of Reserve Stand 1/: Reproduction	Poles	Timber: Trees	Poles and Timber
						%	%	%	%
3	200	25.8	0.2	40.3	30	18.4	23.6	1.4	20.8
6	1,488	4.0	0	4.0	0	63.3	6.5	0	5.3
1	12	0.8	0	0.5	0	2.8	1.4	0	1.2
2	0	0.3	0	1.1	0	0	1.0	0	0.5
4	900	5.9	0	6.0	0	62.8	9.7	0	8.8
7	°	3.4	0	4.8	0	°	8.2	0	6.3
Av.	544	6.2	0.03	8.6	4	28.2	10.2	0.2	8.3

° No data

1/ Percentage loss: Reproduction = Computed loss on slash burn area ÷ actual base no. on slash burn area only.
Poles and timber = actual loss per acre (using acreage of slash burn area) ÷ stand per acre (using entire plot data).
"Reserve stand" taken as after initial logging kill.

Average losses from burning were 544 seedlings and 6.2 poles per acre, representing about 28 percent and 10 percent of the numbers of seedlings and trees remaining after logging. These rates of loss refer to the portions of the plots on which slash was piled and burned. If based on the stand on the entire area, the corresponding percentages would be 15 percent and 6 percent. One of the outstanding features of this form of loss is its extremely wide variation from plot to plot[3/]. This is largely the result of differences in weather conditions at time of burning and in care exercised: Plots 1 and 2, where loss was negligible, were burned immediately after a rain and the fires were given close attention; the others were burned from 5 to 8 days later and were less carefully attended. Stand conditions also materially affect loss. On plot 3, for instance, several slash piles were in dense pole thickets, where normally they should not have been burned at all unless snow-covered. There appears but little relation to volume cut (the listed order of plots) because of the predominant influence of these other factors. The range of losses shown in table 5 is thus representative of what may be expected on different areas and in different years or times of year. The general average loss, particularly that for reproduction, may be a little high for national forest sale areas in this region. [4/]

3/ The loss in reproduction, having been computed on a proportional basis as explained, probably shows wider variations than would actually be found between 5-acre or 10-acre units. Thus, there must have been some loss on Plot 2 and more than indicated on Plot 1, but it happened that the logging loss on non-disposal portions was relatively greater than on burned portions, obscuring the true loss by burning. The reverse may have been true on Plot 6, thus exaggerating apparent burning loss. Hence the figures for single plots are unreliable, but the general average should be roughly indicative of slash burning loss in reproduction.

4/ The division of TM suggests that the author bring out the fact that this experimental cutting and its supervision was not a NF enterprise. Same for slash disposal.

LOSSES CAUSED BY INSECTS AND WINDTHROW

The killing of a few trees by barkbeetles may be considered an almost normal occurrence following a logging operation. Such attacks on living trees are made by beetles attracted to the area by the presence of fresh slash or by those which developed in and emerged from the stumps and unutilized tops. In number of trees, losses are usually greatest in the small pole size (3 inches to 6 inches d.b.h.) and are caused chiefly by pine engraver beetles (Ips confusus, Ips oregoni, and others) in this locality. Occasional larger trees are attacked by Dendroctonus brevicomis and D. valens. As a rule these losses comprise but a small proportion of the reserve stand and the attacks cease after a year or two (1, 2). (Annual surveys of this area showed barkbeetle losses continuing at a rate greater than "normal" for four years after cutting.) Since this is such a common form of loss, insect kill for the first year after logging is included in this summary.

Table 6.- Trees killed by barkbeetles

Plot No.	Number killed per acre		Volume Loss per acre		Percentage of Reserve Stand		
	Poles	Timber Trees	Cu. Ft.	Bd. Ft.	Poles	Timber Trees	Total
3	4.2	0.2	21.3	83	3.8	1.3	3.5
6	0.3	0.1	2.0	5	0.5	0.7	0.5
1	3.8	0.4	15.8	44	6.7	4.4	6.4
2	0.9	0.3	18.5	94	2.8	1.0	2.0
4	2.4	0.1	5.5	10	3.9	1.3	3.7
5	1.4	4.3	216.6	1025	2.9	12.2	6.8
7	0.2	0.1	4.7	18	0.5	0.8	0.6
Av. 1/	2.0	0.2	11.3	41	3.3	1.4	2.9

1/ Data for plot 5 omitted in average.

Table 6 shows that the average loss of uninjured trees from barkbeetle attack was 2.0 poles and 0.2 timber trees per acre, equivalent to 3.3 percent and 1.4 percent respectively of the reserve stand. If desired, the logging damaged trees subsequently killed by insects (table 3) could be added to these, making a total of 2.5 poles and 0.3 timber trees per acre or 4.2 percent and 2.5 percent, respectively. The wide variation in barkbeetle kill from spot to spot is seen in the data for individual plots. Loss varied from 4 trees containing 20 cubic feet on Plot 6 to 57 trees containing 2,166 cubic feet or 10,250 board feet on Plot 5. The heavy loss on the latter plot was due partly to the attack of many trees scorched by accidental fire and should not be taken as typical; values for this plot are not included in the general average. Losses bear no definite relation to amount of cut or reserve.

A systematic ten percent survey of the entire cutting area one year after logging indicated a loss from barkbeetle attack of 0.1 timber tree or 20 board feet per acre. Although this is about one-half the average rate of loss given in table 6, it is within the normal range to be expected in sampling such a variable quantity. Loss of poles by insect attack was not determined in this survey.

Destruction of uninjured trees by windthrow was almost negligible - only one tree on the seven plots or 0.1 percent of the number of timber trees reserved. To this might be added the two logging damaged trees which were subsequently windthrown, making a total loss per acre of 0.04 trees, or 2.3 cubic feet, or 11 board feet. Windfall is another form of loss which may be decidedly variable from place to place and in different years. Moreover, the effect of selective cutting in increasing the

susceptibility of certain trees to windthrow is not limited to the year or two immediately after logging but continues for many years or decades. Wind damage is usually very small in the locality where this study was made, and in the last 15 years has not been excessive anywhere in the central Idaho ponderosa pine type. An extensive survey of several cut-over areas indicated an average annual loss since logging of 0.02 trees or 8.6 board feet per acre from this cause. On single cutting units with unfavorable soil and stand conditions the loss was as much as four times this amount.

The death of 10 pole-size Douglas fir trees on Plot 3 was ascribed to drought,[4/] as no other agency was in evidence and the trees were in such positions that the sudden removal of the overstory could conceivably have caused excessive drying of the surface soil and a high rate of transpiration. "Winter kill" is a possibility. This rather unusual form of loss was equivalent to 0.14 trees per acre, containing 0.12 cubic feet, or 0.3 percent of the number of reserve poles.

LOSSES CLASSIFIED BY SPECIES AND SIZE OF TREES

Losses and injuries as discussed so far included both ponderosa pine and Douglas fir and were segregated into only three size classes - reproduction, poles, and timber trees. A classification by species and smaller size groups is presented in Tables 7 and 8 and in Figure 1 to show which suffered the most damage.

4/ Because of the uncertainty of identification of the cause of this loss and its relative minor extent, it should not be mentioned in any published material.

Table 7.- Classification of Reserve Tree Losses by Cause, Species, and Size.

(All Plots Together)

D.B.H. Class (In.)	Felling	Skidding	Subs. Deaths	Tot. Logging	Slash Burn	Insects and Wind	Total 1/	Felling	Skidding	Subs. Death	Tot. Logging	Slash Burn 2/	Insects and Wind	Total 1/
	Number of Trees Per Acre							Percentage of Reserve Trees 3/						
						PONDEROSA PINE								
4	2.33	3.17	0.38	5.88	4.79	1.30	11.97	5.2	7.1	0.8	13.1	10.7	2.9	26.7
6	.63	.36	.04	1.03	.94	.13	2.10	5.5	3.1	0.3	8.9	8.2	1.1	18.2
8	.17	.06	.02	.25	.15	.10	.50	4.2	1.5	0.5	6.2	3.7	2.5	12.4
10	.12	.03	.03	.18		.05	.23	3.9	1.0	1.0	5.9	-	1.6	7.5
12	.06	.01	.01	.08		.03	.11	2.3	0.4	0.4	3.1	-	1.2	4.3
14	.08	.01	.06	.15	.03	.06	.24	3.3	0.4	2.5	6.2	1.2	2.4	9.8
16	.12		.01	.13			.13	6.7		0.5	7.2			7.2
18	.11		.01	.12		.03	.15	5.8		0.5	6.3		1.6	7.9
20			.01	.01			.01			0.8	0.8			0.8
22	.01			.01		.02	.03	1.2			1.2		2.4	3.6
24	.03			.03		.02	.05	5.6			5.6		3.7	9.3
26	.03			.03			.03	12.0			12.0			12.0
Total	3.69	3.64	.57	7.90	5.91	1.74	15.55	4.9	4.8	0.7	10.4	7.8	2.3	20.5
						DOUGLAS FIR								
4	.20	.39	.03	.62	.18	.42	1.22	5.0	9.7	0.7	15.4	4.5	10.5	30.4
6	.10	.04		.14	.09	.03	.26	9.9	4.0		13.9	8.9	3.0	25.8
8	.07	.01		.08			.08	17.5	2.5		20.0			20.0
10	.03			.03			.03	7.5			7.5			7.5
12	.01			.01			.01	4.0			4.0			4.0
14														
16	.01			.01			.01	3.1			3.1			3.1
24	.01			.01			.01	10.0			10.0			10.0
Total	.43	.44	.03	.90	.27	.45	1.62	5.7	5.8	0.4	11.9	3.6	6.0	21.5
						BOTH SPECIES								
4	2.53	3.56	0.41	6.50	4.97	1.72	13.19	5.2	7.3	0.8	13.3	10.1	3.5	26.9
6	.73	.40	.04	1.17	1.03	.16	2.36	5.8	3.2	0.3	9.3	8.2	1.3	18.8
8	.24	.07	.02	.33	.15	.10	.58	5.4	1.6	0.5	7.5	3.4	2.2	13.1
10	.15	.03	.03	.21		.05	.26	4.3	0.9	0.9	6.1		1.4	7.5
12	.07	.01	.01	.09		.03	.12	2.5	0.4	0.3	3.2		1.1	4.3
14	.08	.01	.06	.15	.03	.06	.24	2.8	0.4	2.1	5.3	1.1	2.1	8.5
16	.13		.01	.14		.	.14	6.1		0.5	6.6			6.6
18	.11		.01	.12		.03	.15	5.1		0.5	5.6		1.4	7.0
20			.01	.01			.01			0.6	0.6			0.6
22	.01			.01		.02	.03	1.1			1.1		2.2	3.3
24	.04			.04		.02	.06	6.1			6.1		3.1	9.2
26	.03			.03			.03	10.3			10.3			10.3
Total	4.12	4.08	.60	8.80	6.18	2.19	17.17	4.9	4.9	0.7	10.5	7.4	2.6	20.5

1/ Total on area with slash burned; for portion of area with no disposal, subtract slash burn loss.

2/ Plot 5 trees included in base No.'s per acre, but not in slash burn losses.

3/ Percentages are based on total trees intended to be reserved; i.e., including all trees killed by logging as well as subsequently. Thus percentages for subsequent deaths do not agree with previous tabulations.

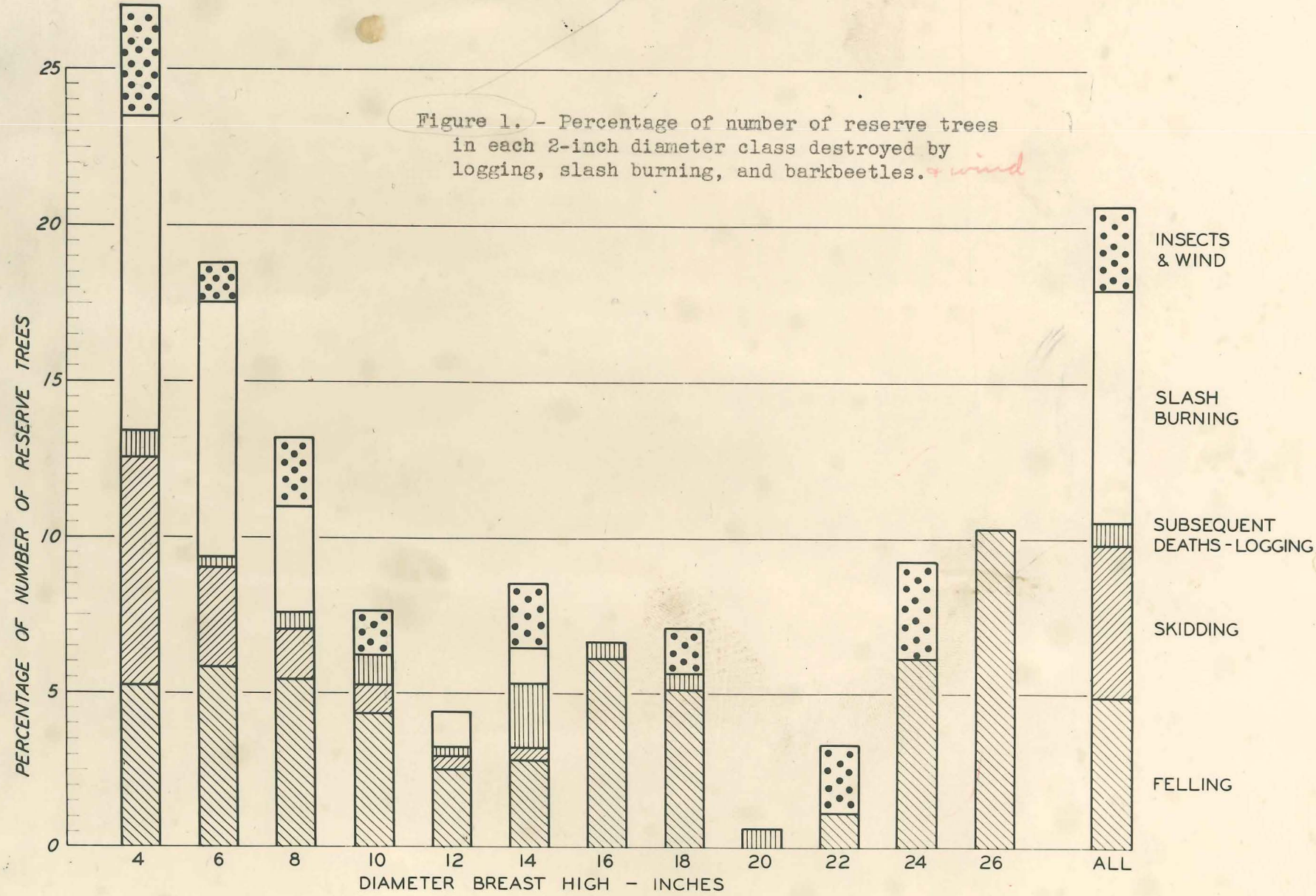

Figure 1. - Percentage of number of reserve trees in each 2-inch diameter class destroyed by logging, slash burning, and barkbeetles.

The relative losses of all Douglas fir trees 3.6 inches d.b.h. and larger were slightly greater than those of ponderosa pine, but the difference is insignificantly small. Killing of fir trees of pole size (4 - 9 inches d.b.h.) was appreciably greater than that of pine, but for larger trees it was slightly less. For either or both species the losses in numbers are by far the greatest in the 4 - 5-inch class, dropping off sharply with increasing diameter. This trend follows that of the curve of number of original or of reserve trees, as would normally be expected in uneven-aged stands. On a percentage basis, as shown in Figure 1, however, the losses are seen to be appreciable on up to the 26-inch class, which included the largest trees destroyed. The percentage losses caused by skidding and by slash burning also tend to follow the number of trees curve, as smaller trees are so much more subject to destruction than larger ones. This is less true of damage caused by felling and by barkbeetle attack, so that their proportional losses are relatively constant through all size classes.

Ponderosa pine and Douglas fir show essentially similar trends of relative logging losses and total losses according to diameter. Fir losses from barkbeetle attack were low in number but high in proportion compared with pine, and they were all in the 4 and 6-inch classes. The percentage of number of pine trees killed by barkbeetles was only one-third that of fir, but losses were distributed through nearly all diameter groups so that percentage volume loss was more than double that of fir.

The classification of reproduction losses in Table 8 fails to show distinct relationships to either species or size class, with the exception of an appreciably higher rate of loss (80 and 76 percent) in the lowest size class (seedlings less than one-half foot high). Considering the

nature of the main causative agencies - skidding and fire - there is no reason to expect marked differences in species and possibly not in size within the size range of trees classed as "reproduction". On the portion of the area with slash burned the average rate of loss for Douglas fir was 50 percent, compared to 62 percent for ponderosa pine, and the ratio between species seems to hold fairly well through all size classes. This difference is more apparent than real, however, because a large proportion of the fir was on one plot where burning losses were very low.

Table 8.- Classification of Reproduction Losses by Species and Size Class

Size Class	AREA WITH NO SLASH DISPOSAL						AREA WITH SLASH BURNED					
	No. Trees Per Acre			Percent of Original Number			No. Trees Per Acre			Percent of Original Number		
	Pine	Fir	Both	Pine	Fir	Both	Pine	Fir	Both	Pine	Fir	Both
0.0-0.5' high	76	41	117	97	59	80	64	130	194	89	71	76
0.6-2.5' "	98	34	132	37	36	37	139	187	326	48	40	43
2.6-4.5' "	145	41	186	38	42	38	261	150	411	60	58	59
4.6'-1" d.b.h.	171	36	207	41	59	43	206	42	248	69	48	64
1" "	229	23	252	37	29	36	180	36	216	63	45	59
2" "	107	7	114	35	50	36	99	12	111	68	55	66
3" "	57	4	61	36	29	36	41	5	46	49	36	47
Total	883	186	1,069	40	43	40	990	562	1,552	62	50	57

INJURIES CLASSIFIED BY SPECIES AND SIZE OF TREES[5/]

In the discussion of logging injuries to trees still living (page 11 and table 4), it was stated that Douglas fir suffered to a greater extent than ponderosa pine and that damage was relatively greater in trees above pole size than in smaller sizes. These relationships are shown in greater detail in table 9. Although the numbers of trees per acre injured are much greater in the 4-inch-to 12-inch-diameter classes than in larger classes,

5/ This section would probably be omitted in any published material, as of minor significance.

the percentages of total reserve show an increase with increasing diameter up to about the 10-inch class, above which the proportion holds fairly even, with minor ups and downs. This is true for both pine and fir and is in distinct contrast to the relation of size of tree to proportion destroyed (Table 7, Figure 1). Injury to reproduction was noted only for size classes larger than one-half foot high; among these classes the number per acre injured decreased with increasing size, but the proportion of total varied only within narrow limits.

The relationship to different forms of damage varies somewhat with size and species. Top breakage was confined to trees 18 inches d.b.h. and smaller, with the highest proportion in about the 12-inch class. The percentage of trees side-swiped by felling was relatively constant for all sizes of ponderosa pine, but increased up to the 10-inch class for Douglas fir. The average proportion of fir trees side-swiped was 6.8 percent, compared to 3.1 percent for pine. Lean caused by logging, a relatively serious form of injury, was recorded for only 1 percent of the reserve trees; the 4-inch class appeared to show the highest rate of injury, but no definite relation to diameter could be shown because of the small number of trees. The proportion of trees with serious scars increased from the 4-inch to the 10-inch class; for larger trees the trend was irregular from one 2-inch class to the next, but averaged high and constant. Scarring was slightly more prevalent on fir than on pine. Of the 25 trees larger than 33 inches d.b.h.on the plots, none was injured by logging.

Table 9.- Classification of logging injured trees by species, size, and nature of injury
(All Plots Together)

D.B.H. Class	Kind of Damage: Top Broken	Side-swiped	Lean	Scar	Total	Top Broken	Side-swiped	Lean	Scar	Total
	Number of Trees Per Acre					Percentage of Reserve Trees				
					PONDEROSA PINE					
4	.75	1.00	0.54	1.17	2.58	1.9	2.5	1.4	3.0	6.6
6	.23	.42	.08	.58	1.01	2.3	4.0	0.8	5.6	9.8
8	.15	.07		.28	.37	4.1	1.9		7.5	10.1
10	.07	.10		.21	.32	2.4	3.4		7.3	11.2
12	.11	.11		.22	.29	4.6	4.6		9.1	12.0
14	.03	.07	.02	.13	.19	1.2	3.0	0.6	5.4	8.4
16	.03	.08	.01	.11	.21	1.7	5.0	0.8	6.7	12.6
18	.06	.11		.07	.18	3.1	6.3		3.9	10.2
20		.06		.04	.10		4.3		3.2	7.5
22		.01		.06	.07		1.7		6.8	8.5
24		.03		.03	.06		5.3		5.3	10.6
26		.01		.01	.03		6.2		6.2	12.5
28										0
30		.03		.01	.03		28.6		14.3	28.6
32 & up										0
Total	1.43	2.10	0.65	2.92	5.44	2.1	3.1	1.0	4.3	8.0
					DOUGLAS FIR					
4	.04	.10	.06	.11	.27	1.2	2.8	1.6	3.2	7.6
6		.04		.03	.07		4.7		3.1	7.8
8	.01	.02		.03	.04	4.3	4.3		8.7	13.0
10	.02	.07		.06	.10	3.7	18.5		14.8	25.9
12	.01				.01	5.9				5.9
14		.10			.10		25.9			25.9
16		.04		.01	.06		13.6		4.6	18.2
18		.01	.01	.03	.05		6.2	6.2	12.5	12.5
20		.03		.01	.04		11.8		5.9	17.7
22				.01	.01				20.0	20.0
24		.01		.03	.04		16.7		33.3	50.0
26		.03			.03		66.7			66.7
28										
30										
32		.01			.01		33.3			33.3
34 & up										
Total	0.08	0.46	0.07	0.32	0.81	1.2	6.8	1.0	4.8	12.0
					BOTH SPECIES					
4	.79	1.10	.60	1.28	2.85	1.8	2.6	1.4	3.0	6.6
6	.23	.46	.08	.61	1.08	2.1	4.1	0.7	5.4	9.7
8	.17	.09		.31	.41	4.1	2.1		7.6	10.3
10	.08	.17		.27	.42	2.6	5.2		8.2	12.9
12	.12	.11		.22	.30	4.7	4.2		8.3	11.5
14	.03	.17	.02	.13	.29	1.0	6.2	0.5	4.7	9.2
16	.03	.12	.01	.12	.27	1.4	6.4	0.7	6.4	13.5
18	.06	.12	.01	.10	.21	2.8	6.3	0.7	4.9	10.5
20		.09		.05	.14		5.5		3.6	9.1
22		.01		.07	.08		1.6		7.8	9.4
24		.04		.06	.10		6.8		9.1	15.9
26		.04		.01	.06		15.8		5.3	21.1
28										
30		.03		.01	.03		22.2		11.1	22.2
32		.01			.01		7.1			7.1
34 & up					0					0
Total	1.51	2.56	0.72	3.24	6.25	2.0	3.4	1.0	4.3	8.4

DECREASE IN STOCKED AREA

The seriousness of the losses in numbers of trees discussed above can not be properly appraised without consideration of the distribution of the destroyed trees over the area. It is conceivable that a thinning out of dense thickets of reproduction or even of stands of poles and larger trees might be more beneficial than harmful. A fair measurement of distribution of losses and remaining trees is provided by a summary of reproduction quadrats on a stocking basis; i.e., the number or proportion of quadrats bearing one or more living trees before and after logging. The data in table 10, based on 600 quadrats each 0.002 acre in area (6.6 feet by 13.2 feet), show the degree of stocking by trees of each of 3 size-classes as well as the 3 together.

The average stocking before logging was 78.4 percent, which may be considered fairly satisfactory. (In a virgin pine stand, 100 percent stocking on the basis used here would rarely be found except on selected spots of not more than a few acres.) On the portions of plots with no slash disposal, i.e., where destruction was caused largely by logging, the proportion of quadrats stocked decreased 12.4 percent. On the portions where slash was piled and burned, the decrease was 29.6 percent, more than double the loss on the no-disposal areas. The difference of 17.2 percent may be ascribed to burning.

The data for stocking by the 3 size classes of trees indicate that by far the greater part of the decrease was due to losses of reproduction. The reduction in stocking by timber trees, which represents approximately the change produced by cutting alone, averaged only 3.5 percent, although this is equivalent to a drop of 50 percent of the original stocking by timber

Table 10.- Percentage of quadrats stocked before and after logging on areas with no slash disposal and on areas with slash piled and burned.

Plot No.	Reproduction			Poles			Timber Trees			Any Size Class		
	Before Log.	After Log.	Decrease	Before Log.	After Log.	Decrease	Before Log.	After Log.	Decrease	Before Log.	After Log.	Decrease
	%	%	%	%	%	%	%	%	%	%	%	%
				On Areas with No Slash Disposal								
3	83	62	21	37	28	9	2	0	2	85	67	18
6	75	63	12	7	5	2	0	0	-	77	65	12
1	80	73	13	12	10	2	7	0	7	85	72	13
2	80	60	20	5	0	5	20	10	10	80	65	15
4	88	78	10	12	12	0	2	0	2	92	82	10
5	22	20	2	15	8	7	17	15	2	43	38	5
Ave.	72.5	60.8	11.7	16.1	12.1	4.0	6.1	2.9	3.2	77.8	65.4	12.4
				On Areas with Slash Piled and Burned								
3	85	50	35	30	20	10	0	0	-	88	55	33
6	88	40	48	5	0	5	0	0	-	88	40	48
1	55	40	15	2	0	2	5	0	5	62	40	22
2	92	69	23	5	4	1	15	9	6	97	78	19
4	77	33	44	15	13	2	8	2	6	83	45	38
5	33	12	21	13	7	6	10	8	2	50	23	27
Ave.	72.3	42.0	30.3	11.3	7.2	4.1	7.8	4.1	3.7	78.8	49.2	29.6

1 pole per .003–.005 acre should be sufficient stocking for 4-10" poles
1 tree " .005–.02 " " " " " 12-24" trees
Therefore use of .002 acre quadrats to measure stocking is misleading and the results should be viewed with suspicion.

trees. (The low figures for this class and for poles are to some extent misleading because the size of quadrat was really not adapted to such material; the relative changes are properly indicated, however.) The absolute decrease in stocking by poles and timber trees was practically the same on areas with slash left on the ground and areas with slash burned, although the relative decrease in pole stocking was somewhat greater on the latter.

The change in stocking seems to show in general a less serious loss than the numbers of trees indicated. For a true comparison of the two modes of expressing loss, the decreases in stocking should be expressed as percentages of original, giving 15.9 percent and 37.6 percent respectively for the no-disposal and slash-burned areas. The corresponding percentages of decrease in number of trees are 39.6 percent and 55.9 percent (all species and size classes together). A more detailed comparison may be made by listing each size class separately, as in Table 11. Here, the number of timber trees marked for cutting as well as those destroyed are included in "losses", since the two were not separable in the stocking tally.

Table 11.- Comparison of relative losses in number of trees and decreases in percentage of quadrats stocked

	REPRODUCTION	POLES	TIMBER TREES	TOTAL
Areas with no slash disposal:				
Percentage decrease in number of trees	40.3	15.2	47.2	39.6
Percentage decrease in stocking	16.2	24.8	52.5	15.9
Areas with slash piled and burned:				
Percentage decrease in number of trees	56.8	24.5	47.3	55.9
Percentage decrease in stocking	41.9	36.3	47.4	37.6

It is noteworthy that while losses of reproduction on the two bases are similar to the average figures previously stated, the losses of poles appear more severe on the stocking basis, and the decrease in timber trees is about the same on both bases. As to poles, this suggests a concentration of heavy losses in patches - a condition which would naturally result from destruction by felling and burning and to a lesser degree from skidding. In the area of unburned slash, the reproduction losses were fairly well scattered, as indicated by the decrease of only 16 percent in stocking compared to 40 percent in numbers. In the area where slash was burned, the losses were not only much greater, but their distribution was more unfavorable, as shown by the comparatively high decrease in degree of stocking. In general, the decrease in stocking, even though less than in numbers of trees, is still high enough to be of serious consequence. The excessive loss on the slash-burned area, a large part of which should be avoidable, reduced the final stocking to less than 50 percent, which is far from satisfactory.

COMPARISON WITH RESULTS OF PREVIOUS STUDIES[6/]

One of the uses of such studies as this is to compare the destructiveness of various methods of logging and of slash disposal under various conditions of stand and methods or degrees of marking, as an aid in dictating methods that will reduce losses in future operations. For this purpose the present study of only one operation is of limited value, but its results may be compared with such data as are available from a few previous studies in ponderosa pine forests. Logging damage and slash disposal losses must

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6/ This section, although of interest for comparison here, repeats much familiar data and would be condensed or only casually mentioned in any published report.

be considered separately, and subsequent losses from barkbeetles and wind omitted. True comparisons of logging methods alone are difficult because of the variables in original stand, topography, soil, and degree of cutting, and are further complicated by differences in method of study and particularly the failure of most previous reports to clearly distinguish felling and skidding damage. The data in table 12 are roughly indicative of some of the differences found, however.

The proportion of reproduction (40 percent) destroyed on this Idaho area appears to be about average for Caterpillar tractor logging operations, with their various modifications. Perry (5) found a greater loss (69 percent) where tractor and big wheels were used, but a very small loss (3 percent) where a skidding drum was used to bring in logs to the main wheel roads. The scanty data on horse or horse and wheel skidding indicate a lower rate of loss than with Caterpillars (with exception of last mentioned combination) as might be expected. The data for steam skidding operations in California (1, 6) indicate a loss with supervised ground lead system but little greater than for tractors, but materially higher, running up to complete destruction, with high lead.

The loss of pole-size trees (12 percent) was not greatly different from that for the tractor-wheel operation in central Oregon (13 percent), the tractor-pan operation in Montana (9 percent), and tractor-wheel and tractor-arch logging in California as cited by Brown (1). It was appreciably higher than the tractor operation in Northeastern California (5 percent), the tractor operation in Arizona (0 percent), and the tractor-wheel-drum operation in Oregon (0 percent). Compared to the latter, a large part of the excess loss is probably due to the relatively large number of poles (average, 66 per acre) found in mixture or in groups closely adjoining sawlog trees in the Boise Basin area.

Table 12.- Logging damage. Percentage of trees destroyed in selective logging of ponderosa pine by various skidding methods and in several regions.

REFERENCE, REGION, AND SKIDDING METHOD	PERCENTAGE DESTROYED: Reproduction	Poles**	Timber Trees	NOTES
Boise Basin, Idaho				
Tractor bunching) Tractor-arch yarding)	40	12	3	Av. stocking decrease 16 percent of original
Perry (5)				
Deschutes N.F., Oregon				
Horses	15	0	0)	
Tractor, wheels, and skidding drum	3	0	0)	Stand very variable
Tractor, wheels	69	13	0)	
Lidgerwood skidder	23	33	2)	
Weidman (8)				
Central Oregon				
Tractor, arch	30-40 (area)	°	°	
Anderson (cited in (8)				
Western Montana				
Tractor, pans	°	9	1	
Berry (cited in (8)				
N.E. California				
Tractor alone	27 (area)	5	1	
Wales (7)				
Arizona				Stocking decrease, 22 percent of original
Tractor	30	0	0	
Show (6)				
California				
Horses, big wheels	20	°	°	Timber loss, high lead, is that in mid and near zones from spar trees; includes some living broken-topped trees.
Ground lead	36	°	°	
High lead	100-45	°	77	
Tractor bunching) Tractor-arch yarding)	30 (approx.)	°	°	

° No data given

** Poles 4 inches to 11 inches; timber trees 12 inches and up, in this table.

Brown (1)			
California			
Horses, big wheels	20-35	negligible	Poles and timber trees not segregated.
Tractor, big wheels	25-50	5-10	
Ground lead, supervision	25-50	10-15	
High lead, modified, regulated	25-50	10-15	Some of these operations would not class as selective cuttings.
Tractor, arch	25-50	10-15	
Track skidders	25-50	10-15	
Tractor, big wheels, unregulated	45-65	15-20	

Table 12 (continued)

Ground lead, unreg.	50-75	15-25	
Modified high lead	50-75	10-25	
High lead, unregulated	50-95	25-75	
Brown (1)			
Southwest			
Horses	7.1 percent of area complete kill of reproduction		
	11.4 percent of area partial kill of reproduction		
Tractor	14.3 percent of area complete kill of reproduction		
	31.0 percent of area partial kill of reproduction		

Destruction of reserve trees of timber size (3 percent) appears to have been greater on this operation than on other caterpillar and horse logging operations and even than the one Lidgerwood skidder operation reported. As has been mentioned, most of this loss was in felling, and as it is not clear in several of the other reports whether or not felling damage was fully included, it is questionable if this is a genuine difference.

Specific data on damage to the stand by various methods of slash disposal in different localities are even more scanty than for logging damage. One of the main reasons for this scarcity has been expressed by Pearson (4): "Because of the many variables involved, it seems futile to attempt to give figures on the proportion of seedlings killed by different methods of slash disposal." Mention has been made of these variables above (pp. 2, 13) but the writer believes that the publication of a considerable quantity of such data (accompanied by full information or attendant conditions) is nevertheless justified, in order that forest managers may give this factor due weight without extensive local trials.

Table 13.- Slash disposal losses. Percentage of trees destroyed (based on original stand before logging) by various methods of slash disposal in 3 regions.

REFERENCE, REGION, AND SLASH DISPOSAL METHOD	PERCENTAGE DESTROYED: Reproduction	Poles	Timber Trees	PERCENTAGE DECREASE IN STOCKING
Boise Basin, Idaho				
Pile and Burn	17 (no.)	9	0.1	22
Munger & Westveld (2)				
Oregon				
Pile and Burn (Ser. A plots)	5 (area)	2	0	°
" " " (Ser. B plots)	°	13	0	°
Swamper burn	2 (area)	negligible		°
Spot burning	19-77 (area)	10	0	°
Broadcast	55-91 (area)	31-100	0-79	°
Show (6)				
California				
Broadcast	88 (no.)	°	°	61

° No data

The most thorough discussion of losses incident to several methods of slash burning is that of Munger and Westveld (2) for several operations in Oregon and Washington. They show relative destruction of reproduction on an area basis, which is a more meaningful expression than numbers, but probably yields lower loss percentages than the latter. The exact relation between the two and between either of them and quadrat stocking percentage is not known, and in fact would probably show a rather wide range of variation, as was suggested by the single-plot data used as a basis of table 10. It is apparent, however, that losses on the Boise Basin area were considerably above the average, probably near the maximum of those reported by Munger

(Series A plots). The destruction of pole-size trees averaged more than four times as great on the Idaho area. Inasmuch as the average number per acre left after logging, slash burning, and first-year insect losses was still more than six times as large on the Idaho as on the Oregon areas, the greater loss was really not as serious as might appear from the tabular figures. On the other hand, the same publication cites other areas (Series B plots), where burning was done under dangerous weather conditions, on which the damage to poles was considerably greater than the average for the Boise Basin area.

The other methods of slash disposal on the Oregon-Washington areas may be compared as follows: The losses caused by swamper burning were almost negligible, but that method is of limited application, especially in Idaho, where logging is largely a "fair weather" job. Spot burning was generally more destructive than piling and burning, showing a wide range of from 19 to 77 percent of area of reproduction destroyed and pole losses of about 10 percent. Broadcast burning is so highly destructive to advance reproduction and reserve trees, as indicated by both the Oregon and California figures, that it is no longer allowed on Forest Service sales and but little practiced elsewhere. No specific data were available on losses incident to other slash disposal methods which are used occasionally, such as lopping and scattering, pulling tops, and no disposal (latter used on part of Boise Basin area), but they may be assumed to be smaller than those of any burning method and therefore negligible.

CONCLUSIONS: VALUE OF THE STUDY

Since essentially only one method of logging - tractor skidding - was used on the plots, no specific conclusions as to method to be recommended on the basis of damage to forest growth can be made, except as follow from doubtful comparisons with results elsewhere. Even with the one skidding method, the variation in stand and reproduction conditions makes difficult any general prescription or setting of allowable numerical limits of destruction. ~~difficult.~~ As to felling damage, there is undoubtedly room for improvement. The penalty scale provision in timber sale contracts could be more rigidly enforced and "rules" such as suggested by Wales (7) could be set up.* More than anything else there is the need to obtain the sympathy of the loggers with the idea of saving reserve trees and reproduction. And this is not as impossible as some might surmise; a few of the old-time hard-boiled or "high-ball" loggers may never become "converted", but persistent and tactful local campaigns, particularly involving personal contacts with men of all classes in the logging concern, would have a material and worthwhile effect.

The use of Caterpillar tractors, with or without various accessories such as big wheels, fairlead arches, and skidding drums, has proved so efficient and has been adopted so widely on large operations in the ponderosa pine region that it is useless to consider prohibiting it in favor of less destructive horse logging, at least where other conditions dictate tractor logging. Steam skidding has been largely abandoned as uneconomical in this type except in special situations or as supplementary to tractor logging, so that its relatively destructive effect need not be of much further concern.

* Similar suggested requirements are also listed in the Region 4 Timber Management Handbook (1938), p. 10.

The Lidgerwood skidder operation cited by Perry (5) shows that damage may be held to moderate proportions with careful supervision and under particular conditions of stand and topography. Within the field of tractor logging, it is believed that damage can be held to an acceptably low figure in three ways: (a) Developing and requiring the use of special equipment, such as the skidding drum and line described by Perry (5), where it will not unduly increase the cost of logging; (b) Making a detailed logging plan and prescribing and enforcing rules of operation as suggested by Wales (7) and Weidman (8); and (c) "Logger education", as mentioned in the last paragraph.

The choice of slash disposal methods (excluding broadcast burning) is ordinarily made on the basis of costs and protection needs rather than of damage to forest growth, although the latter element is given some weight. Therefore, the results of the present study, even to the limited extent that it provides any comparison of methods, do not dictate that piling and burning either should or should not be practiced in central Idaho. They do show that burning of piled slash must be conducted with care and under proper weather conditions if excessive losses are to be avoided. Considerable extra expenditure in placement and construction of slash piles, in waiting for suitable weather and in burning under what may be difficult conditions from the ~~standpoint~~ view of the personnel is justified if it means a saving of 63 percent of the reproduction or 24 percent of the pole stand (the extreme losses recorded in this study). The modern trend toward partial disposal of slash, generally in the form of cleaning up thoroughly on strips through an area or accumulations in dangerous spots, may make the question of burning damage of minor importance, inasmuch as

only a small percentage of the area is covered by burning. At the same time, the large saving in cost per acre by partial disposal should make possible greater care in burning on the designated portions.

One of the chief values of the data presented here is to give the forest manager an approximation of the absolute and relative losses and the range of such losses incident to selective logging under the conditions described. He may take measures to reduce their magnitude where feasible, and may also allow for them in calculations of future growth and stand development. This study may be considered as one of a series of investigations, those in other regions already cited and future studies in other localities and under different methods and conditions, all of which will provide a body of facts and figures that will facilitate a fairly close estimate of damage under any given set of conditions and thus contribute in a major way to decisions as to logging and slash disposal methods.

SUMMARY

1. The losses and injury to reserve stand and reproduction caused by a selective logging operation in the ponderosa pine type of central Idaho were studied on seven 10-acre sample plots representing various intensities of cutting and a limited variety of stand conditions.

2. Destruction of trees by felling and by skidding long logs with Caterpillar tractors amounted to 1,070 seedlings and saplings, 7.5 poles, and 0.7 timber trees per acre. These losses are equivalent to 40.5, 11.4, and 3.9 percent of the numbers of each class intended to be left.

3. The number of trees seriously injured but not killed by logging averaged 6.2 per acre or 8.4 percent of the reserve stand.

4. First-year losses of trees so severely injured that they were windthrown or fell prey to barkbeetle attack added about 1 percent to the proportions of poles and timber trees destroyed. Uninjured trees also suffered excessive losses from barkbeetle attack within the first year--an average of 2.0 poles and 0.2 timber trees per acre, or 3.3 and 1.4 percent of the numbers reserved. Windfall loss was negligible.

5. On the portion of the area where slash was piled and burned, an average of 544 seedlings and saplings and 6.2 poles per acre were killed by fire, equivalent to 28.2 and 10.2 percent of the post-logging stand of these two classes of trees. The loss varied widely on the 7 plots, from almost nothing to more than twice the average proportions.

6. Relative losses of trees larger than 3.6 inches d.b.h. classified by diameter classes and causes show for most causes a sharp decline with increasing size. Relative losses of reproduction, on the other hand, were fairly similar for all of the 7 size classes distinguished, except for a higher rate in the lowest class (0-$\frac{1}{2}$ foot high). Species differences were insignificant.

7. Percentage of area stocked by trees of any size was reduced from 78 percent before logging to 65 percent after logging on the area with no slash disposal, and to 49 percent on the area with slash piled and burned. These decreases of 13 percent and 29 percent respectively present a truer picture of losses than numbers alone, at least for trees of reproduction size.

8. Compared with reports from other regions and judged by field observations, direct logging damage was higher than it should be. Using the same methods it could probably be reduced one-fourth to one-half by giving

more weight to this element in logging planning, by enforcement of rules governing felling and skidding, and by promoting the idea of conservation among loggers.

9. Destruction by slash burning was abnormally high on some plots. It can and should be held to low and acceptable limits by greater care and burning only in wet weather or snow.

10. The data provide a tentative standard for an operator or forest manager to judge the corresponding losses in any similar operation or to make approximate allowance for same. They will serve a much wider and more useful function in the planning of timber cuttings and slash treatment only after combining with similar studies of a wider variety of conditions of stand, reproduction, topography, soil, degree of cutting, and methods of logging and slash disposal.

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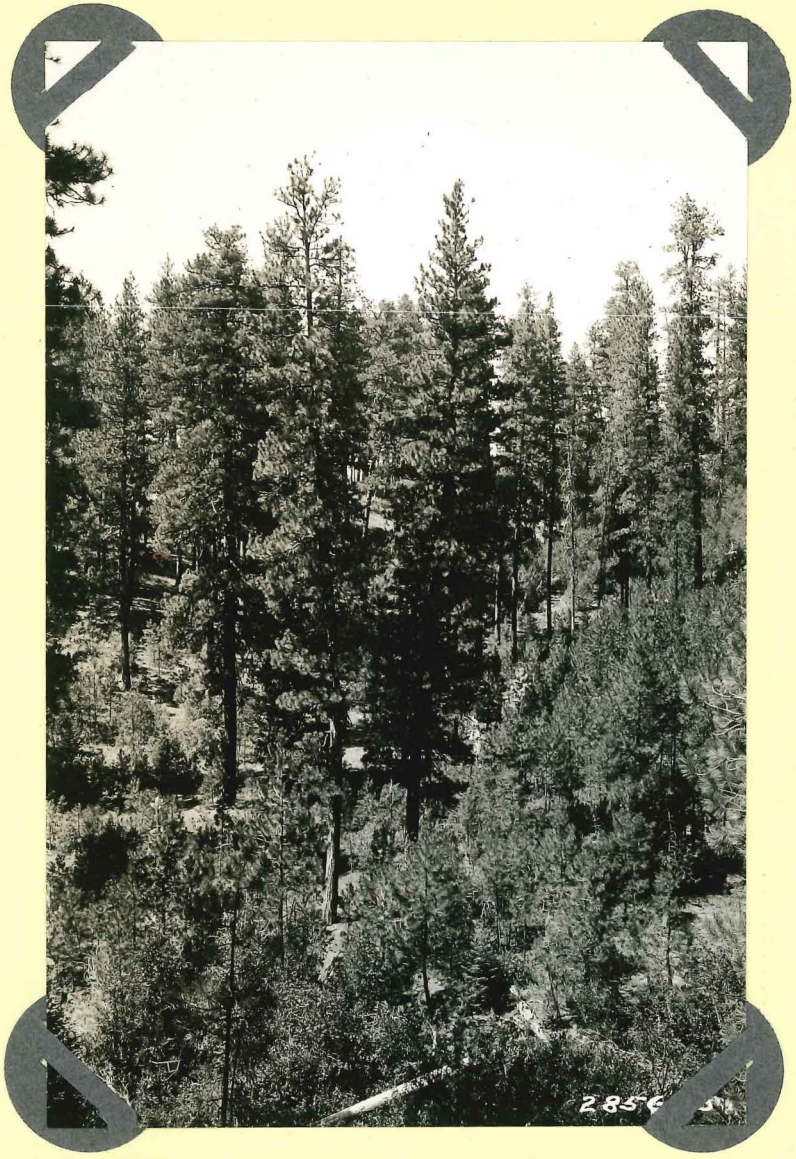
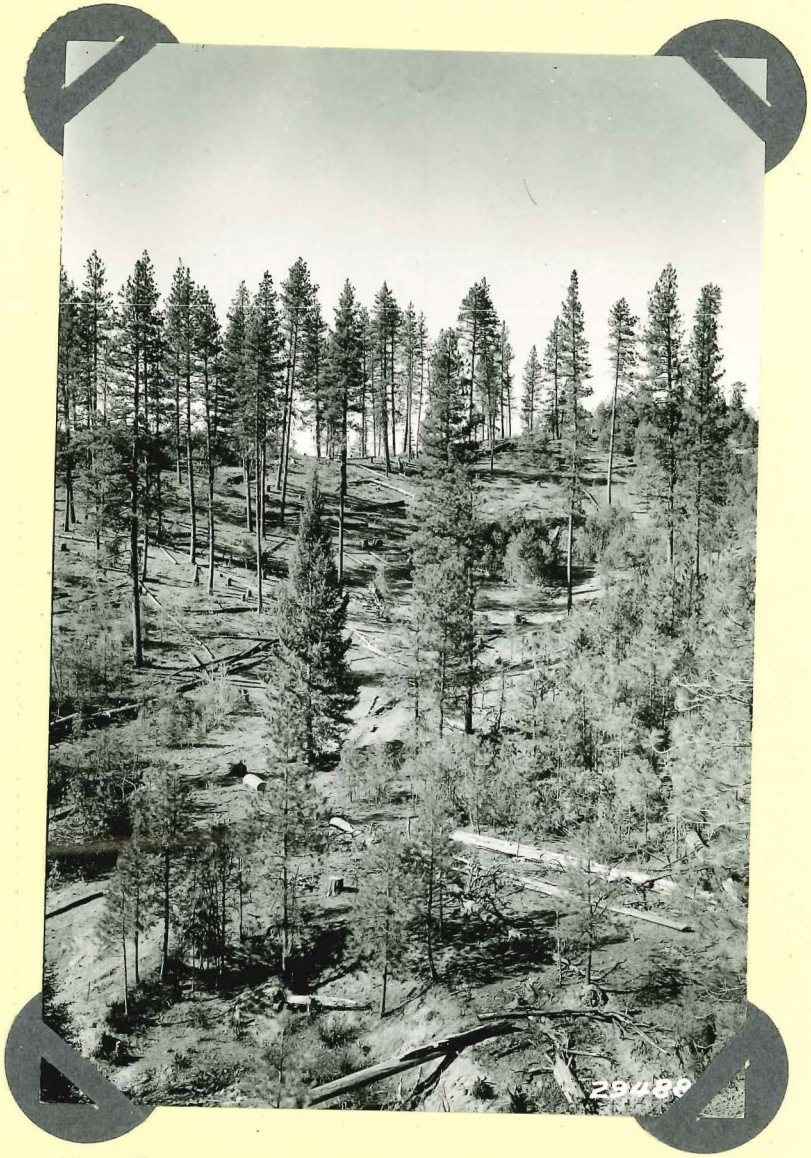


Fig. 2. A. Ponderosa pine stand in Boise Basin, Idaho, before logging (Sample plot No. 6).

Boise Photo # FM-189



B. The same view one year later, after tractor logging and slash disposal. The stand was cut by the "tree class selection" method.

Boise Photo # FM-282

A

B

of plot 6

Fig. 3. A series of views, showing destruction of reproduction by tractor logging and slash burning. A - Before logging, seedlings and saplings scattered irregularly under an open stand of older trees. B - The same view after logging, before slash disposal.

A - Boise Photo # FM-190
B - " " # FM-180
C - " " # FM-283 (over

C

C - The same view as A and B one year later, after slash had been piled and burned.

A

B

Fig. 4. Destruction of reproduction in a dense thicket of saplings through which logs were skidded from above. A - Dense stand of reproduction before logging. B - A few trips through with the tractor and it looks like this. Plot 6.

A- Boise Photo # FM 179
B- " " " FM 181
C- " " " FM 186

C

C - The same spot as A and B a year later, after slash had been piled and burned.